Search for the Identification of 3EG J1835+5918: Evidence for a New Type of High-Energy Gamma-ray Source

N. Mirabal and J. P. Halpern

Astronomy Department, Columbia University, 550 West 120th Street, New York, NY 10027

abulafia@astro.columbia.edu,jules@astro.columbia.edu

M. Eracleous

Department of Astronomy and Astrophysics, The Pennsylvania State University,

525 Davey Laboratory, University Park, PA 16802

mce@astro.psu.edu

R. H. Becker

Physics Department, University of California, Davis, CA 95616

bob@igpp.llnl.gov

Received ______________________; accepted ______________________

Accepted by *The Astrophysical Journal*

ABSTRACT

The EGRET source 3EG J1835+5918 is the brightest and most accurately positioned of the as-yet unidentified high-energy γ-ray sources at high Galactic latitude ($\ell, b = 89°, 25°$). We present a multiwavelength study of the region around it, including X-ray, radio, and optical imaging surveys, as well as optical spectroscopic classification of most of the active objects in this area. Identifications are made of all but one of the *ROSAT* and *ASCA* sources in this region to a flux limit of approximately 5×10^{-14} erg cm^{-2} s^{-1}, which is 10^{-4} of the γ-ray flux. The identified X-ray sources in or near the EGRET error ellipse are radio-quiet QSOs, a galaxy cluster, and coronal emitting stars. We also find eight quasars using purely optical color selection, and we have monitored the entire field for variable optical objects on short and long time scales without any notable discoveries. The radio sources inside the error ellipse are all fainter than 4 mJy at 1.4 GHz. There are no flat-spectrum radio sources in the vicinity; the brightest neighboring radio sources are steep-spectrum radio galaxies or quasars. Since no blazar-like or pulsar-like candidate has been found as a result of these searches, 3EG J1835+5918 must be lacking one or more of the physically essential attributes of these known classes of γ-ray emitters. If it is an AGN it lacks the beamed radio emission of blazars by at least a factor of 100 relative to identified EGRET blazars. If it is an isolated neutron star, it lacks the steady thermal X-rays from a cooling surface and the magnetospheric non-thermal X-ray emission that is characteristic of all EGRET pulsars. If a pulsar, 3EG J1835+5918 must be either older or more distant than Geminga, and probably an even more efficient or beamed γ-ray engine. One intermittent *ROSAT* source falls on a blank optical field to a limit of $B > 23.4, V > 23.3$, and $R > 22.5$. In view of this conspicuous absence, RX J1836.2+5925 should be examined further as a candidate for identification with 3EG J1835+5918 and possibly the prototype of a new class of high-energy γ-ray source.

Subject headings: gamma rays: observations — pulsars: general – radio continuum: galaxies — X-rays: general

1. Introduction

One of the most important advances in high-energy astrophysics in recent years is the discovery of 271 persistent high energy γ-ray sources by the EGRET instrument aboard the Compton Gamma-ray Observatory (*CGRO*, Hartman *et al.* 1999). While the detection of these sources is a major success, identification of their nature and origin has turned out to be a more challenging task. The principal method of identification, which relies on statistical evidence that blazars are the dominant population, is to find positional coincidences between EGRET sources and flat-spectrum radio/millimeter sources (Thompson *et al.* 1995, 1996; Mattox *et al.* 1997; Bloom et al. 1997). By definition blazars are flat-spectrum, radio-loud AGNs with polarized and variable optical emission. Although numerous efforts have been made at various wavelengths, only about one third of all EGRET sources have been identified with any degree of confidence. On the latest count these identifications include 66 blazars, *i.e.*, flat-spectrum radio quasars or BL Lac objects (Hartman *et al.* 1999), seven rotation-powered pulsars (Hartman *et al.* 1999, Kaspi *et al.* 2000, Ramanamurthy *et al.* 1995), the nearby radio galaxy Cen A, and the Large Magellanic Cloud. Therefore approximately 196 EGRET sources remain unidentified with roughly half of these located at high Galactic latitude, $b > 10°$.

Many difficulties attend the identification of EGRET sources close to the Galactic plane, but even at high Galactic latitude, the size of the typical error circle and the lack of a tight relation between gamma-ray flux and other properties such as X-ray flux and core radio flux prevent all but the brightest counterparts from being identified securely on the basis of position alone. The absence of obvious counterparts also admits the possibility that there is another population with characteristics unlike the identified EGRET sources. We have decided to explore the latter possibility by means of detailed work at other wavelengths, while in the long term the situation should improve considerably with the next generation high-energy γ-ray mission *GLAST*, which will produce more precise source locations.

We have chosen for a case study the unidentified EGRET source 3EG J1835+5918. This object may be the best candidate for the prototype of a new population different from blazars or pulsars. It is the brightest of the as-yet unidentified EGRET sources at high Galactic latitude ($\ell, b = 89^\circ, 25^\circ$), and the one with the smallest error circle. Because it is strongly detected and well away from the confusing diffuse emission in the Galactic plane, 3EG J1835+5918 is localized to within a radius of only $12'$ at 99% confidence, which makes a deep multiwavelength search for a counterpart feasible. The latest analysis of the EGRET observations of 3EG J1835+5918 leads to the conclusion that it shows no strong evidence for variability (Reimer *et al.* 2000). Its spectrum can be fitted by a power law of photon index –1.7 from 70 MeV to 4 GeV, with a turndown above 4 GeV. Such temporal and spectral behavior is more consistent with a rotation-powered pulsar than a blazar. Unlike 3EG J1835+5918, blazars are highly variable, and exhibit steeper spectra.

Prior to the observations reported herein, there were no known active galactic nuclei (AGNs) or pulsars in the error circle of 3EG J1835+5918. Examination of existing catalogs finds no flat-spectrum radio source (Mattox *et al.* 1997), no 1.4 GHz radio source of any type brighter than 4 mJy in the NRAO-VLA Sky Survey catalog (NVSS, Condon *et al.* 1998), and no 4.85 GHz source brighter than 20 mJy (Becker, White, & Edwards 1991). Observations by Nice & Sayer (1997) find and no radio pulsar to an upper limit of 1 mJy at 770 MHz. Furthermore, all of the known gamma-ray blazars and pulsars appear brighter in X-rays than the upper limit that we shall present for 3EG J1835+5918. In light of these facts, 3EG J1835+5918 cannot be a blazar unless it is a radio-quiet one (requiring a redefinition of this concept), nor a pulsar unless, as we shall show, it is one with unprecedented characteristics.

In this paper we present the results of radio, X-ray, and optical observations of the location of 3EG J1835+5918. The outline of the paper is as follows: §2 describes our multiwavelength data acquisition and selection techniques. §3 describes the optical spectroscopy of candidates and the overall results. §4 details notable properties of individual objects and assesses their prospects as the identification of 3EG J1835+5918. Multiwavelength comparisons with known γ-ray sources are addressed in §5, and the implications and conclusions of our work are discussed in §§6 and 7.

2. Observations

2.1. Optical Photometry and QSO Candidate Selection

The principal body of optical data for this study is a series of standard UBV and Cousins R CCD images of the error circle of 3EG J1835+5918 which we obtained using the MDM Observatory 1.3m telescope during a photometric run in 1998 June and July. A thinned, back-illuminated 2048 × 2048 SITe CCD was used to cover a $17' \times 17'$ field with multiple exposures. A mosaic of four such overlapping fields enabled us to observe a $32' \times 32'$ region centered on the most likely EGRET source position (B. Dingus, private communication). Our images thus cover the entire 99% confidence region specified in the Third EGRET Catalog (Hartman *et al.* 1999), which can be approximated as an ellipse of major axis $24'$. In 1997 July we had covered the same field in the V and I bands only, and all of the V-band images were used to search for variability on long (year) and short (hours to days) time scales. The images were processed using standard IRAF/DAOPHOT procedures. Approximately 5000 objects were measured inside a $15'$ radius circle. The photometry described here was calibrated using Landolt standard stars (Landolt 1992). Typical limiting detections achieved were $U = 22.1, B = 23.4, V = 22.5$, and $R = 22.5$. Galactic extinction in this field is small but not negligible; Schlegel, Finkbeiner, & Davis

(1998) give $E(B-V)=0.045$, corresponding to $A_U=0.25$, $A_B=0.20$, $A_V=0.15$, and $A_R=0.12$. Magnitudes quoted in this paper are observed, *i.e.*, not corrected for extinction.

We derived a list of QSO candidates from this photometry using the standard ultraviolet excess selection technique. Following Hall *et al.* (1996), we required plausible quasar candidates to have either $(B-V)<0.4$ and $(U-B)>-0.3$, or $(B-V)<0.6$ and $(U-B)<-0.3$. This selection is effective in separating QSOs from the stellar locus, and is efficient in detecting them out to $z=2.2$ (Hall *et al.* 1996; Fan 1999). We note that of the current identifications in the 3EG catalog, which are unbiased by optical selection, the largest redshift is only $z=2.286$, and all of their optical counterparts are brighter than $V=22.1$. Our color selection should also permit the discovery of any object that has a power-law continuum, which produces a UV excess, and especially a synchrotron spectrum which peaks above the optical band, *e.g.*, those blazars commonly referred to as high-energy peaked. Thus, our technique is sensitive to most of the known EGRET blazars, and useful to search for a UV excess counterpart that might be expected on the basis of the absence of strong radio emission.

The major complication in this search comes in separating quasars from white dwarfs, blue field stars, and compact emission-line galaxies which often have similar blue colors and are known major contaminants of quasar color surveys. Further criteria can be applied using additional colors, but we decided to allow maximum freedom in the selection criteria in order to avoid excluding possibly interesting candidates. A total of 40 such candidates to a limiting magnitude of $B=21$ were selected for follow-up spectroscopy. In subsequent sections of this paper we discuss the eight QSOs that were discovered in our spectroscopic observations.

2.2. X-ray Observations

A total of three X-ray observations were made that cover the entire 99% error ellipse of 3EG J1835+5918, two by the *ROSAT* High Resolution Imager (HRI) and one by *ASCA*. The first *ROSAT* observation took place on 1995 February 2–4, with a total exposure time of 9,186 s. Five point-like X-ray sources were detected in this image, which reached a minimum detectable intrinsic flux of 7.4×10^{-14} erg cm^{-2} s^{-1} in the 0.1–2.4 keV band, assuming a power-law spectrum with photon index 2.0 and Galactic $N_{\rm H} = 4.6 \times 10^{20}$ cm^{-2}. A longer HRI observation of the same field was obtained between 1997 December 15 and 1998 January 20, with a total exposure time of 61,269 s. This deeper observation detected a number of fainter X-ray sources above a limiting unabsorbed flux of $\approx 2 \times 10^{-14}$ erg cm^{-2} s^{-1}, including four of the five previous sources, as well as 10 new ones. Nine sources fall within the 99% confidence ellipse of 3EG J1835+5918. All of these sources are listed in Table 1, together with information about their optical identifications, which are radio-quiet QSOs or coronal emitting stars. The HRI astrometry was recalibrated using the optical counterparts of five well-localized X-ray sources, for which an average translation of $2.''3$ was required. After this shift, the five fiducial X-ray sources have a dispersion of only $0.''8$ from their optical positions. In Table 1 we list optical position, or recalibrated X-ray position in the case that no firm optical identification has been made. X-ray fluxes are calculated assuming a power law of photon index –2.0 and the full Galactic $N_{\rm H}$ for QSOs and unidentified sources, and a Raymond-Smith thermal plasma of $T = 3 \times 10^6$ K and $N_{\rm H} = 1 \times 10^{20}$ cm^{-2} for stars.

An *ASCA* observation took place from 1998 April 20–22 for a total clean exposure time of $68,900$ s in each of the two Gas Imaging Spectrometers (GIS). Figure 1 shows the combined GIS image. The detection threshold for this *ASCA* observation was 1.1×10^{-13} erg cm^{-2} s^{-1} (1–10 keV) assuming a photon index of –1.7. Several sources are detected far from the EGRET error ellipse, and only one faint source falls within it, a radio-quiet QSO at $z = 0.973$ that was also detected by *ROSAT*. In Table 1 we give information about this and four additional *ASCA* sources outside the EGRET error ellipse that we were able to identify.

Diffuse X-ray emission at the western edge of the *ASCA* GIS image appears to be coming from an uncatalogued cluster of galaxies that is evident on our CCD images. We have not attempted to measure the X-ray flux of this source as it is too close to the edge of the detector and may extend outside it. The brightest galaxies in this vicinity are members of the cluster at $z = 0.102$ and have $R \approx 14$ and $R \approx 15$, at J2000 coordinates $18^{\rm h}32^{\rm m}38\overset{\rm s}{.}01, +59^\circ23'43\overset{''}{.}8$, and $18^{\rm h}32^{\rm m}49\overset{\rm s}{.}52, +59^\circ21'49\overset{''}{.}4$, respectively. This X-ray source is well outside the 3EG J1835+5918 error ellipse, and we have no reason to suspect that they are related. In particular, there is no evidence of an AGN in this cluster.

The field of view of the *ASCA* Solid-state Imaging Spectrometer (SIS) detectors, even when operated in 4-CCD mode during this observation, is too small to cover the EGRET error ellipse. No X-ray sources were detected in the SIS images, so we do not discuss them further here.

2.3. Radio Observations

We reduced an archival VLA observation of this field which was taken at a frequency of 1.4 GHz on 1995 February 21 in the D configuration. We found 14 sources stronger than 2.5 mJy in the neighborhood of 3EG J1835+5918. They have a positional accuracy of approximately $7''$ for the fainter sources, and $1''$ for sources stronger than 15 mJy. For completeness, we examined the NVSS catalog at the same frequency to confirm six more faint sources that were marginally detected in the 1995 pointing. To incorporate information at other radio frequencies, we searched the Westerbork Northern Sky Survey (WENSS), which covered this field to a limiting flux of 18mJy at 326 MHz (Rengelink et al. 1997), and the NRAO 4.85 GHz catalog of Becker *et al.* (1991), which has a flux limit of 20 mJy at this location. A combined total of 20 radio sources were found inside and outside the error ellipse. Their properties are listed in Table 2, and their positions are shown in Figure 2. Most notably, there are no flat-spectrum sources in this field, and there are only three sources within the 99% confidence error ellipse of 3EG J1835+5918, all fainter than 4 mJy at 1.4 GHz.

3. Optical Spectroscopy and Results

We used a number of spectrographs to obtain moderate-resolution spectra of candidate X-ray and radio counterparts as well as UV excess objects selected from our optical imaging survey. These instruments include the Goldcam spectrograph on the KPNO 2.1m telescope, the Mark III spectrograph on the MDM 1.3m McGraw-Hill and 2.4m Hiltner telescopes, the Kast double spectrograph on the 3m Shane reflector at Lick Observatory, the Low Resolution Spectrograph (LRS) on the Hobby-Eberly telescope, and the Low Resolution Imaging Spectrograph (LRIS) on the Keck II telescope. Most spectra were analyzed independently by two authors and an agreement on classification was reached after comparing separate findings. The spectra were analyzed for emission and absorption lines and classified as either as star, galaxy, white dwarf, AGN, or uncertain. We have completed spectroscopy to a limiting magnitude of $B = 20.3$, which includes 43 out of 53 optical candidates. In addition we have spectra of two objects fainter than $B = 20.3$. Finding charts for the classified objects are given in Figures 3 and 4, and their spectra are shown in Figures 5 and 6.

Thus far we have found eight QSOs by the UV excess technique in the magnitude range $18.5 < B < 21.3$. Their redshifts range from 0.504 to 2.21. These are listed in Table 3 and their positions are shown in Figure 2. By design, they all fall within or very close to the 3EG J1835+5918 error ellipse. The efficiency of our color selection agrees fairly well with the number counts reported by Koo & Kron (1998) and Hall *et al.* (1996), which would predict that six QSOs with $B < 20.3$ and $z < 2.3$ would be found within a region of this size. Several additional candidates were found to have featureless blue spectra that we cannot securely classify. Since their colors are consistent with those of white dwarfs, we suspect that they are of the weak-lined (DC) variety.

Of the X-ray sources, six have been identified with radio-quiet QSOs, including five that were independently selected by UV excess colors. A seventh X-ray quasar is an *ASCA* and radio source at $z = 0.668$ that lies well outside the EGRET error circle. Four more X-ray sources are identified with coronal emitting stars of types G, K, and dMe whose X-ray fluxes are normal for their optical magnitudes.

Two radio sources outside the EGRET error ellipse are identified with bright, early type galaxies at redshifts of 0.106 and 0.156, respectively, that lack any emission lines or evidence of non-stellar continuum in their optical spectra (Figure 6). Neither of these are promising γ-ray source candidates. The lower-redshift galaxy is close to the X-ray emitting galaxy cluster that is west of the EGRET error ellipse and it is apparently a member of the cluster.

We have had less success in identifying the faint radio sources within the EGRET error ellipse. Bright optical objects near their positions have proven to be ordinary stars, indicating that their true optical counterparts are likely to be fainter than our limiting magnitude for spectroscopy. Finding charts for both of the radio galaxies, as well as for several unidentified radio sources, are displayed in Figures 3 and 4.

4. Notes on Individual Interesting Objects

RX J1834.1+5913: This is the brightest quasar in the EGRET error ellipse ($V = 18.8$, $z = 0.973$) and it is detected by both *ASCA* and *ROSAT*. Its X-ray flux decreased between the two ROSAT observations, from 1.9×10^{-13} erg cm^{-2} s^{-1} in 1995 to 4.76×10^{-14} erg cm^{-2} s^{-1} in 1997–98. However, we are cautious about this variability since the source was near the edge of the detector in the later observation. We have several optical measurements of it in 1997, 1998, 1999 which also show modest variability. The largest change of 0.39 magnitudes occurred between 1998 June and 1999 September, but there is no evidence for rapid variability on time scales of days. In addition, the equivalent width of its Mg II emission line did not vary in spectra taken at two different epochs. Thus, the spectral and variability properties of RX J1834.1+5913 offer no strong reason to argue that it is a candidate identification for 3EG J1835+5918. However, as the brightest QSO in the EGRET error ellipse, it does warrant continued scrutiny. In §5, we compare the properties of this source to those of the identified EGRET blazars in order to illustrate how unusual any AGN counterpart of 3EG J1835+5918 must be.

UVQ J1834.3+5926: At $z = 2.21$, this is the highest redshift QSO that we have found near 3EG J1835+5918. Its optical spectrum is somewhat unusual in that it is the reddest of all the QSOs in this field, and its emission lines are broad but weak. We suspect that its Ly α line, which falls just blueward of our Keck spectrum, is responsible for boosting its U-band flux and helping it to meet the UV excess criterion.

RX J1834.4+5920: This relatively bright *ROSAT* source (5.3×10^{-14} erg cm^{-2} s^{-1}, assuming a $T = 3 \times 10^6$ K thermal plasma spectrum) remains unidentified, although it lies near the edge of the HRI detector where the point-spread function is very poor. An M star of magnitude $R = 17.8$ has been suggested as a possible identification even though it lies $15''$ from the X-ray position (Carramiñana *et al.* 2000).

VLA J1834.7+5918: This faint radio source of 3.7 mJy remains without spectroscopy, yet a blue optical object with $V = 21.4$ falls just inside the western boundary of its error circle (see Figure 3). Although lacking X-ray emission, it is still a possible quasar or BL Lac object and worth further study, especially spectroscopy of the optical candidate. Since this is the brightest and most promising radio source of those within the EGRET error ellipse, we adopt its radio flux as an upper limit for 3EG J1835+5918 in subsequent discussion.

VLA J1835.1+5906: This is the brightest radio galaxy ($R = 15.1,\ z = 0.156$) at the edge of the EGRET error ellipse. Its optical spectrum was examined for any evidence of a BL Lac object in its nucleus, the principal indicator of which would be a shallower than normal break at 4000 Å. However, no such evidence is seen. This plus its steep radio spectrum, $\alpha = -0.53$ between 1.4 and 4.85 GHz and absence of X-ray emission argue against VLA J1835.1+5906 being a BL Lac identification of 3EG J1835+5918.

VLA J1835.6+5939 (=AX J1835.7+5939): This is a quasar at $z = 0.668$ and the brightest radio source near 3EG J1835+5918, with a 1.4 GHz flux of 359 mJy. However, it is outside of the 99% error ellipse by $8'$, and this plus its steep radio spectrum, $\alpha = -0.84$ between 1.4 and 4.85 GHz, argue against considering it as a strong γ-ray candidate.

RX J1836.2+5925: This is perhaps the most intriguing object found in all of our searches. It was the brightest X-ray source within the error ellipse (1.6×10^{-13} erg cm^{-2} s^{-1}), at least during the second *ROSAT* observation, but it was undetected in the first *ROSAT* pointing or in the *ASCA* observation. Thus, it must have varied by at least a factor of 2 in the long term, although it emitted steadily over the one-month span which comprises the second *ROSAT* observation. RX J1836.2+5925 of interest here primarily because it does not have an optical counterpart in any color (Figure 7) to limits of $U > 22.3, B > 23.4, V > 23.3$, and $R > 22.5$. A red stellar object of $R \approx 19.7$ is located $11''\!.4$ west of the X-ray centroid, but it is not a viable candidate given the precision with which several other X-ray sources in this field line up with their established optical counterparts. As described above, the HRI astrometry in this figure was recalibrated using the optical counterparts of five well-localized X-ray sources, for which an average translation of $2.''3$ was required. After this shift, the five X-ray sources have a dispersion of only $0.''8$ from their optical positions. Thus, the illustrated error box which is $8''$ on a side must include the true position beyond a reasonable doubt.

None of the optical objects near the error box of RX J1836.2+5925 show any proper motion which could account for their positional discrepancy with the X-ray source. We have not obtained spectroscopy for any of these faint neighbors, but a deeper and more exhaustive optical study of this X-ray source would be important to evaluate its qualifications as a possible new type of γ-ray source counterpart. By the definition of Stocke et al. (1991), this X-ray source has an X-ray to optical flux ratio $f_X/f_V > 78$. Such a high ratio is found only among low-mass X-ray binaries and isolated neutron stars. As we argue below, neither of these object classifications would make 3EG J1835+5918 compatible with the broad-band spectra of the well-identified EGRET sources.

If RX J1836.2+5925 is not the counterpart of 3EG J1835+5918, then it might be similar to the newly discovered class of luminous soft X-ray transients that have been found by *ROSAT* in the nuclei of non-active galaxies. These are as luminous as 10^{44} erg s^{-1} and last for several months (Grupe, Thomas, & Leighly 1999; Komossa & Greiner 1999; Komossa & Bade 1999). A promising interpretation of these events is tidal disruption and accretion of stellar debris by a central black hole. If RX J1836.2+5925 is such an event, then it could reside in a host galaxy at $z \approx 0.5$ which deeper optical imaging could detect.

5. Multiwavelength Comparisons to Known Classes of EGRET Sources

5.1. Blazars

Our radio, optical, and X-ray data on active objects in the field of 3EG J1835+5918 can be compared with other identified EGRET sources to evaluate whether 3EG J1835+5918 can still fall within the multiwavelength parameters of any of the known classes of γ-ray emitters. Beginning with blazars, Figure 8 shows radio, optical, X-ray, and γ-ray fluxes of the sample of well-identified EGRET blazars defined by Mattox *et al.* (1997, and personal communication). *ROSAT* and *Einstein* fluxes are taken from Fossati *et al.* (1998), and V magnitudes and total 4.85 GHz radio fluxes from Mattox (personal communication). The EGRET spectral points from 3EG J1835+5918 are taken from Reimer *et al.* (2000). Of the numerous candidate identifications which we could superpose, we chose two, namely, the brightest QSO within the error ellipse (RX J1834.1+5913, $z = 0.973$), and the brightest radio source within the error ellipse (VLA J1834.7+5918). For the latter, we hypothesize that the suggestive $V = 21.4$ optical identification is correct, and we graph an X-ray upper limit from the deeper *ROSAT* observation. For the QSO, we assign an upper limit of 0.5 mJy at 1.4 GHz, from the VLA image.

The smooth curves fitted to these two candidates correspond to the sum of two empirical third-order polynomials as applied by Comastri *et al.* (1995). This is not a model of blazar emission, but only a guide to the eye in making empirical estimates of the peak fluxes at low and high energy. In doing so we assume the presence of two emission mechanisms, a low-energy synchrotron component and a high-energy component peaking in the γ-ray band, possibly due to inverse Compton scattering.

While the optical and X-ray properties of our brightest candidates are not unprecedented, they lie at the faint end of the distributions. In particular, the X-ray upper limit for VLA J1834.7+5918 (or any of the other radio sources in the error ellipse) falls below the faintest blazars by at least an order of magnitude. More significant are their faint radio fluxes which, in the case of VLA J1834.7+5918 is two orders of magnitude fainter than the faintest radio counterpart of any well-identified EGRET blazar. RX 1834+5913 is nearly three orders of magnitude fainter in the radio band. Figure 9, in which the ratio of 4.85 GHz flux density to the peak γ-ray flux in the range $E > 100$ MeV is graphed as a function of γ-ray flux for the Mattox blazars, confirms the highly discrepant positions of any of the QSOs or radio sources which are positionally coincident with 3EG J1835+5918 and candidates for identification with it. (We assume in this Figure a flat radio spectrum for 3EG J1835+5918, since none of its faint candidates were actually detected at 4.85 GHz.)

Another property of the majority of EGRET blazars is their rapid and large-amplitude flux variations. The absence of such obvious γ-ray variability from 3EG J1835+5918 already argues against a blazar nature for it (Reimer *et al.* 2000). We have also searched our V-band images obtained in 1997 and 1998 for objects with rapid or extreme optical variability, looking for variations of $\Delta V > 0.3$. Apart from the modest variability of the $z = 0.973$ QSO RX J1834.1+5913 described above, no optical candidates for blazar activity were discovered in this manner.

5.2. Rotation-Powered Pulsars

Similar to the comparison with known blazars, we can examine how 3EG J1835+5918 compares to the EGRET pulsars. In Figure 10, we compare the 0.1–2.4 keV X-ray flux (Becker & Trümper 1997) and average flux $E > 100$ MeV for EGRET pulsars (Fierro 1995; Kaspi *et al.* 2000; Ramanamurthy *et al.* 1995). Any possible pulsar counterpart of 3EG J1835+5918 should be assigned an X-ray flux upper limit equal to the flux of the brightest unidentified *ROSAT* source in the error ellipse. This role is therefore properly assigned to RX J1836.2+5925, although the fact that it is variable in X-rays already places some doubt upon its credentials as a pulsar candidate. Most of the soft X-ray flux observed from intermediate-age neutron stars is surface thermal emission, which should not vary from year to year. However, the additional nonthermal X-ray component which is present in Geminga and other γ-ray pulsars could in principle vary, and Halpern & Wang (1997a) suggested that it does in Geminga. Therefore, we use the quiescent flux upper limit of this source (from the 1995 *ROSAT* observation) for comparison in Figure 10. Such a comparison strains the analogy with Geminga. While the latter is a cooling neutron star with $T \approx 5.6 \times 10^5$ K at $d \geq 150$ pc, 3EG J1835+5918 is about 50 times fainter in X-rays, thus either $d > 1$ kpc, or if it is to be located at a similar distance as Geminga, its surface temperature should be less than 3×10^5 K. The larger distance is problematic, since it implies a γ-ray luminosity of 1.7×10^{35} $(d/1 \text{ kpc})^2$ erg s^{-1} if isotropic, which is at least 5 times larger than the spin-down power of Geminga, 3.3×10^{34} erg s^{-1}. Alternatively, if it is closer than 1 kpc, then its surface must be cooler and it is likely to be older than 3×10^5 yr, which would also strain its γ-ray efficiency. If 3EG J1835+5918 is a pulsar but RX J1836.2+5925 is *not* its counterpart, then its X-ray flux upper limit is reduced to $\approx 5 \times 10^{-14}$ erg cm^{-2} s^{-1}, or 80 times fainter than Geminga.

Younger pulsars such as Vela, PSR B1951+32, and PSR B1706-44 are EGRET sources with luminosities in the range $(1-2) \times 10^{35}$ erg s^{-1}, but 3EG J1835+5918 lacks the nonthermal X-ray emission and synchrotron nebulae that accompany those more luminous pulsars. Furthermore, it would be highly unexpected to find a pulsar of characteristic age $\tau < 1 \times 10^5$ yr at $d \sim 400$ pc from the Galactic plane. since this would require a kick velocity $v > 5000$ $(\tau/10^5 \text{ yr})^{-1}$ km s^{-1}. An interesting possibility would be a recycled millisecond pulsar, which could be old yet energetic. But even such pulsars manage to channel at least 5×10^{-4} of their spin-down power into either thermal (Halpern & Wang 1997b) or nonthermal X-rays (Becker & Trümper 1999; Mineo et al. 2000). In the case of 3EG J1835+5918, any pulsar counterpart would have $L_X(0.1-2.4\ \mathrm{keV})/L_\gamma(>100\ \mathrm{MeV}) < 6\times10^{-5}$, which places a uniquely low limit on the ratio of X-ray to spin-down power.

5.3. Other Possible γ-ray Sources

In addition to the well established classes of γ-ray blazars and pulsars, several associations have been suggested which are highly plausible even while not conclusively proven. Most notable is the radio star and Be/X-ray binary LSI +61°303 (Strickman et al. 1998), long associated with the γ-ray source 2CG 135+01. Similar objects might be the 47 ms pulsar B1259–63 with a Be star companion, detected up to 200 keV (Grove et al. 1995), and the Be/X-ray binary SAX J0635+0533 in the error circle of 2EG J0635+0521 (Kaaret et al. 1999). Since these systems all have neutron stars with Be star companions, their γ-ray emission is not necessarily confined to the pulsar magnetospheric mechanism, but may arise in the interaction of the relativistic pulsar wind with the wind of the companion, or with its radiation. However, all of these systems have bright optical companions, as well as strong X-ray emission at least at some of the time. It is estimated that there are only 200 Be/X-ray binaries within 5 kpc (Rappaport & van den Heuvel 1982); these are young systems which are confined to the Galactic disk. If a Be star binary, the location of 3EG J1835+5918 well away from the Galactic plane would probably make it the nearest such system, and virtually impossible to miss since its V magnitude would be brighter than 9 if at $d < 1$ kpc. Since no such Be star is present in this region, this scenario for 3EG J1835+5918 can safely be ruled out.

6. Implications for EGRET Source Identifications

The statistical issues concerning the identification of EGRET sources with flat-spectrum radio sources were rigorously addressed by Mattox et al. (1997), and it is hardly possible to improve upon that analysis at this time. To summarize, flat-spectrum radio sources are the only AGNs that have been detected by EGRET with any degree of confidence. Unfortunately, while the EGRET survey is flux limited, the radio identifications of EGRET sources in Figure 9 are *not* flux limited, but rather are plagued by source confusion due to the large size of the EGRET error circles and the large surface density of radio sources. Thus, the statistical reliability of EGRET source identifications is lower than that in any other branch of astronomy. As Mattox et al. calculate, the radio sources that are reasonably secure (*i.e.*, $> 95\%$ confidence) identifications of EGRET sources have 5 GHz flux densities > 500 mJy. That is why the correlation between radio flux and γ-ray flux in Figure 9 is weak and less than linear. Below 50 mJy, it is not even possible to make a meaningful argument for identification because the mean separation of such radio sources on the sky is comparable to the size of the EGRET error circles. Accordingly, there are *three* radio sources within the error circle of 3EG J1835+5918, and they are all fainter than 4 mJy. None is an X-ray source. If any one of these radio sources were the true counterpart of the EGRET source, its ratio of radio to γ-ray flux would be two orders of magnitude smaller than that of any known blazar. We are not claiming that 3EG J1835+5918 is unique in this regard. Other unidentified EGRET sources may eventually prove to be similar.

Even though we cannot yet point to a likely identification of 3EG J1835+5918, it is apparent from our multiwavelength observations that the true counterpart must be physically different or extreme in its properties relative to the classes of EGRET sources that have been identified so far. This is true whether the counterpart is one of the candidates studied here, or an undetected fainter object. Furthermore, it is unlikely that a systematic error in γ-ray position has caused us to overlook a more conventional identification. In radio and X-ray we have explored a region approximately 4 times the size of the 99% confidence location, and even within this ample area there are no blazar or pulsar candidates. For example, even if the counterpart were the brightest radio quasar in Figure 1, which is $8'$ from the edge of the 99% confidence region, that object is a steep-spectrum radio source, as are all of the other bright radio sources outside the EGRET error ellipse. Thus, an error of this magnitude in the location of 3EG J1835+5918 will not change the basic conclusion that a new or extreme type of counterpart is responsible.

One possible implication of this result is that radio-steep or radio-quiet quasars could be counterparts of some of the unidentified EGRET sources, despite the analysis of Mattox *et al.* (1997) which argues that such a new population is not needed. Instead of interpreting the hard γ-ray spectrum and lack of variability as pulsar-like, it might be that these properties are also characteristic of the less violently variable AGNs. The obstacle to identifying a potential radio-weak or radio-quiet EGRET source population is not sensitivity, but source overlap. There are simply too many such AGNs in any EGRET error circle. While it is almost certainly the case that weaker radio blazars will be identified with high-energy γ-ray sources once their error circles are reduced by *GLAST*, it remains to be seen whether or not qualitatively different types of AGN will be also be represented.

An interesting scenario for a new type of γ-ray AGN has been suggested by Ghisellini (1999), who posits the existence of blazars whose synchrotron spectrum peaks in the MeV band, and an inverse-Compton component that peaks in the TeV. A variation of such a model could fit the multiwavelength spectrum of the $z = 0.973$ QSO RX J1834.1+5913 or any of the fainter QSOs in the field provided that the proper index for the power-law electron energy distribution can be accommodated, and only if the observed optical emission is dominated by the usual thermal accretion-disk emission so that it can represent an upper limit to the underlying synchrotron power law. In such a model the hard X-ray emission is due entirely to the synchrotron component. The absence of a radio counterpart is naturally explained by the form of the power law, which in this case requires a flat spectral index $\alpha \approx -0.45$ where $F_\nu \propto \nu^\alpha$, thus the power-law index of the electron energy distribution is $p \approx -1.9$. Such a prediction can easily be tested by more sensitive hard X-ray spectra of the QSO RX J1834.1+5913.

Radio-quiet blazars have been hypothesized theoretically (Ghisellini 1999; Mannheim 1993; Schlickeiser 1984) but so far none have been identified (Stocke *et al.* 1990; Jannuzi *et al.* 1993), and it is not even clear what such a phenomenon would mean. Could the multiwavelength properties of 3EG J1835+5918 be evidence of the hadronic model, the so called proton blazar? Such a theory proposes to explain γ-ray emission in blazars, relying on protons accelerated by shocks moving through the jet. The accelerated protons then interact with soft-photons which lead to the creation of pions that further decay and cascade into electron-positron pairs, γ-rays and neutrinos. Such a model (Mannheim 1993) could fit the observations of 3EG J1835+5918 if the energy density ratio of protons to electrons is greater than 10.

If 3EG J1835+5918 is a pulsar, it implies that highly efficient (or highly beamed) γ-ray pulsars can avoid producing soft X-rays at a level below 10^{-4} of their apparent γ-ray luminosity. At least two mechanisms of X-ray emission have been observed to accompany all γ-ray pulsars at such levels or higher (Wang et al. 1998). In the outer-gap model, synchrotron emission from secondary pairs that are produced by conversion of γ-rays in the inner magnetosphere where $B > 2 \times 10^{10}$ G can explain the nonthermal X-ray component from pulsars like Geminga and PSR B1055–52. The second mechanism is thermal emission arising from the heated polar caps that are impacted by the inward-going accelerated particles from the outer-gap accelerator. There is good evidence that polar-cap heating occurs even in recycled pulsars which are *not* detectable EGRET sources (Zavlin & Pavlov 1998; Halpern & Wang 1997b). Therefore, it is difficult to reconcile such a theory, as well as the observational fact that pulsars are X-ray sources of $L_X > 10^{-4}\ I\Omega\dot{\Omega}$, with a pulsar origin for 3EG J1835+5918. If many of the unidentified EGRET sources are similar radio-quiet pulsars in the Galactic plane, X-ray absorption makes them exceedingly difficult to identify, and perhaps they will be revealed only when γ-ray observations are sensitive enough to detect their pulsations independently.

7. Conclusions and Further Work

We identified all but one of the X-ray sources in the field of 3EG J1835+5918 to a flux limit of approximately 5×10^{-14} erg cm^{-2} s^{-1}. These are radio-quiet QSOs [F(1.4 GHz) $<$ 0.5 mJy], coronal emitting stars, and a cluster of galaxies. There are no flat-spectrum radio sources in the vicinity to a flux limit of $\approx$ 20 mJy, and no radio sources in the EGRET error ellipse brighter than 4 mJy at 1.4 GHz. In addition, we find no evidence of a BL Lac object hosted in any low-redshift galaxy. We also found several QSOs, as one would expect, using purely optical color selection. Multiple-epoch optical imaging of the entire EGRET error ellipse has not revealed any notable variability. The discovery of only radio-quiet quasars in the error circle of 3EG J1835+5918 is a sobering development in the search for its identification. Although the γ-ray properties of 3EG J1835+5918 are more similar to those of Geminga and other EGRET pulsars, no other indirect evidence for a pulsar, apart from one unidentified X-ray source (RX J1836.2+5925) whose optical counterpart is probably fainter than $B = 23.4, V = 23.3$, and $R = 22.5$, has been found. Yet, the fact that this X-ray source is variable by at least a factor of 2 would make it unique among rotation-powered pulsars. Taken together, these findings point to the possibility of a truly remarkable object, one that cannot be matched by any known class of γ-ray source.

Even in the absence of a definite identification, it is clear that 3EG J1835+5918 is lacking in one or more of the physically essential attributes of any known class of γ-ray emitter. Its radio flux is at least two orders of magnitude fainter than any of the securely identified EGRET blazars, and its soft X-ray flux is at least 50 times fainter than that of Geminga and similar EGRET pulsars. If it is an AGN it lacks the beamed radio emission of blazars. If it is an isolated neutron star, it lacks the steady thermal X-rays from a cooling surface and the magnetospheric non-thermal X-ray emission that is characteristic of all EGRET pulsars. If a pulsar, 3EG J1835+5918 must be either older or more distant than Geminga, and probably an even more efficient or highly beamed γ-ray engine.

We have plans to complete the optical spectroscopy of fainter candidates in this field to $B \approx 21.5$ and we will also study fundamental properties such as polarization and optical variability of the newly discovered AGNs. Perhaps the most important technique which we have not yet applied is polarimetry. Polarimetry provides a definitive test for synchrotron emission in an ordered magnetic field, and polarization is one of the essential properties of blazars. Perhaps the blazar nature of a radio-quiet beam in an AGN can only be demonstrated in this way. A deeper radio pulsar search would also be warranted. Finally, we will pursue the optical identification of the *ROSAT* source RX J1836.2+5925 to the faintest magnitudes that are necessary in order to find our whether or not it is a neutron star. In combination, these observations may result in the identification of an important EGRET source, and possibly the prototype of a new class of γ-ray emitter.

We thank Eric Gotthelf for his assistance with the reduction of *ASCA* data, Karen Leighly and John Tomsick for assistance with the optical imaging, and John Mattox, Greg Madejski, Brenda Dingus, and Reshmi Mukherjee for helpful discussions. This work was supported by NASA grants NAG 5-3229 and NAG 5-7814.

REFERENCES

Becker, W., & Trümper, J. 1997, A&A, 326, 382

——— 1999, A&A, 341, 803

Becker, R. H., White, R. L., & Edwards, A. L. 1991, ApJS, 75, 1

Bloom, S. D., Hartman, S. D., Teräsranta. H., Tornikoski, M., & Valtaoja, E. 1997, ApJ, 488, L23

Carramiñana, A., *et al.* 2000, Proc Fifth Compton Symposium, in press

Comastri, A., Molandi, S., & Ghisellini, G. 1995, MNRAS, 277, 297

Condon, J. J., Cotton, W. D., Greisen, E. W., Yin, Q. F., Perley, R. A., Taylor, G. B., & Broderick, J. J. 1998, AJ, 115, 1693

Dickey, J. M., & Lockman, F. J. 1990, ARAA, 28, 215

Fan, X. 1999, AJ, 117, 2528

Fierro, J. M. 1995, PhD Thesis, Stanford University

Fossati, G., Maraschi, L., Celotti, A., Comastri, A., & Ghisellini, G. 1998, MNRAS, 299, 433

Ghisellini, G. 1999, APh, 11, 11

Grove, J. E., Tavani, M., Purcell, W. R., Johnson, W. N., Kurfess, J. D., Strickman, M. S., & Arons, J. 1995, ApJ, 477, L113

Grupe, D., Thomas, H.-C., & Leighly, K. M. 1999, A&A, 350, L31

Hall, P. B., Osmer, P. S., Green, R. F., Porter, A. C., & Warren, S. J. 1996, ApJ, 462, 614

Halpern, J. P., & Wang, F. Y.-H. 1997a, ApJ, 477, 905

——— 1997b, BAAS, 29, 1391

Hartman R. C. *et al.* 1999, ApJS, 123, 79

Jannuzi, B. T., Green, R. F., & French, H. 1993, ApJ, 404, 100

Kaaret, P., Piraino, S., Halpern, J., & Eracleous, M. 1999, ApJ, 523, 197

Kaspi, V. M., Lackey, J. R., Mattox, J., Manchester, R.N., Bailes, M., & Pace, R. 2000, ApJ, 528, 445

Koo, D. C., & Kron, R. G. 1988, ApJ, 325, 92

Komossa, S., & Bade, N. 1999, A&A, 343, 775

Komossa, S., & Greiner, J. 1999, A&A, 349, L45

Landolt, A. 1992, AJ, 104, 340

Mannheim, K. 1993, A&A, 269, 67

Mattox, J. R., Schachter, J., Molnar, L., Hartman, R. C., & Patnaik, A.R. 1997, ApJ, 481, 95

Mineo, T. *et al.* 2000, A&A, 355, 1053

Nice, D. J., & Sayer, R. W. 1997, ApJ, 476, 261

Ramanamurthy, P. V. *et al.* 1995, ApJ, 447, L109

Rappaport, S., & van den Heuvel, E. P. J. 1982, in Porc. IAU Symp. 98, Be Stars, ed. M. Jaschek & H.-G. Groth (Dordrecht: Reidel), 327

Reimer, O., Brazier, K. T. S., Carramiñana, A., Kanbach, G., Nolan, P. L., & Thompson, D. J. 2000, Proc Fifth Compton Symposium, in press

Rengelink, R. B., Tang, Y., de Bruyn, A. G., Miley, G. K., Bremer, M. N., Röttgering, H. J. A., & Bremer, M. A. R. 1997, A&AS, 124, 259

Schlegel, D. J., Finkbeiner, D. P. , & Davis, M. 1998, ApJ, 500, 525

Schlickeiser, R. 1984, ApJ, 277, 485

Stocke, J. T., Morris, S. L., Gioia, I., Maccacaro, T., Schild, R.E., & Wolter, A. 1990, ApJ, 348, 141

Stocke, J. T., Morris, S. L., Gioia, I., Maccacaro, T., Schild, R.E. & Wolter, A., Fleming, T. A., & Henry, J. P. 1991, ApJS, 76, 813

Strickman, M. S., *et al.* 1998, ApJ, 497, 419

Thompson, D. J., *et al.* 1995, ApJS, 101, 259

Thompson, D. J., *et al.* 1996, ApJS, 107, 227

Wang, F. Y.-H., Ruderman, M., Halpern, J. P., & Zhu, T. 1998, ApJ, 498, 373

Zavlin, V. E., & Pavlov, G. G. 1998, A&A, 329, 583

This manuscript was prepared with the AAS LaTeX macros v4.0.

Table 1. X-ray Sources in the Field of 3EG J1835+5918

Name	R.A. (h m s)	Decl. (° ′ ″)	B	z	$F_X(0.1-2.4\,\mathrm{keV})$ [a] (erg cm^{-2} s^{-1})	ID
AX J1832.6+5923 [b]	18 32 38.00	59 23 43.8	–	0.102	–	Cluster
AX J1833.3+5928 [b]	18 33 19.62	59 30 05.7	18.9	0.942	6.7×10^{-13}	QSO
RX J1834.1+5913	18 34 08.24	59 13 51.0	19.3	0.973	1.9×10^{-13}	QSO
RX J1834.2+5920	18 34 14.88	59 20 24.5	10.9	–	5.3×10^{-14}	G7 star
RX J1834.3+5909 [b]	18 34 20.36	59 09 15.0	17.8	–	4.8×10^{-14}	dMe star
RX J1834.4+5920	18 34 24.74	59 20 55.6	–	–	5.3×10^{-14}	M5 star? [d]
RX J1835.5+5915	18 35 32.73	59 15 41.1	16.7	–	1.1×10^{-13}	dMe star
AX J1835.6+5939 [b]	18 35 39.87	59 39 50.7	18.4	0.668	2.3×10^{-13} [c]	RL Quasar
RX J1835.9+5923	18 35 53.71	59 23 29.6	19.6	1.87	4.3×10^{-14}	QSO
RX J1835.9+5926	18 35 58.49	59 26 17.5	–	–	5.5×10^{-14}	–
RX J1836.0+5924	18 36 00.36	59 24 53.2	–	–	2.4×10^{-14}	–
RX J1836.1+5925	18 36 08.03	59 25 05.4	–	–	2.1×10^{-14}	–
RX J1836.2+5925	18 36 13.82	59 25 28.9	–	–	1.6×10^{-13}	–
RX J1836.6+5920 [b]	18 36 36.90	59 20 41.9	21.3	1.36	4.1×10^{-14}	QSO
RX J1836.6+5925 [b]	18 36 38.62	59 25 25.5	19.8	1.75	4.8×10^{-14}	QSO
RX J1836.8+5910 [b]	18 36 51.07	59 10 08.3	12.1	–	6.6×10^{-14}	K5 star [d]
RX J1837.0+5934 [b]	18 37 00.56	59 34 17.7	18.5	1.278?	4.2×10^{-13}	QSO

[a] Unabsorbed Flux. For QSOs and unidentified sources, N_{H} is taken from Dickey & Lockman (1990) and $\Gamma = 2.0$ is assumed. For stars, $N_{\mathrm{H}} = 1 \times 10^{20}$ cm^{-2} and $T = 3 \times 10^6$ K are assumed.

[b] Outside EGRET 99% confidence error ellipse.

[c] *ASCA* X-ray flux given in the 1–10 keV band.

[d] Carramiñana *et al.* (2000).

Table 2. Radio Sources in the Field of 3EG J1835+5918

R.A. (h m s)	Decl. (° ′ ″)	R	z	F(1.4 GHz) (mJy)	F(326 MHz) (mJy)	Comment
18 32 12.54	59 18 05.3	–	–	60.0	168.0	No ID [a]
18 32 58.72	59 28 01.8	15.4	0.106	9.5	27.0	Galaxy [a]
18 33 24.94	59 05 05.7	–	–	7.8	–	No ID [a]
18 33 42.08	59 11 26.6	–	–	86.0	280	No ID [a]; F(4.85 GHz) = 38 mJy
18 33 43.03	59 36 27.8	–	–	15.0	21	No ID [a]
18 33 48.78	59 20 04.2	–	–	4.3	–	No ID [a]
18 33 50.55	59 35 31.8	–	–	5.4	–	NVSS, No ID [a]
18 34 12.74	59 32 06.1	–	–	9.0	–	No ID [a]
18 34 43.92	59 24 11.2	–	–	3.4	–	No ID
18 34 46.19	59 18 28.1	–	–	3.7	–	$V = 21.4$?
18 34 47.16	59 38 31.0	–	–	25.0	53	No ID [a]
18 34 50.88	59 36 54.0	–	–	3.2	–	NVSS, No ID [a]
18 34 51.73	59 08 34.7	–	–	2.6	–	NVSS, No ID
18 35 11.71	59 06 46.4	15.1	0.156	204	448	Galaxy, F(4.85 GHz) = 102 mJy
18 35 33.15	59 04 5.2	–	–	3.7	–	NVSS, No ID [a]
18 35 39.81	59 39 51.9	18.3	0.668	359	1329	Quasar [a]; F(4.85 GHz) = 127 mJy
18 35 42.21	59 03 38.8	–	–	6.4	–	NVSS, No ID [a]
18 36 31.63	59 05 46.1	–	–	3.2	–	NVSS, No ID [a]
18 37 28.66	59 32 29.4	–	–	62.0	366 [b]	No ID [a],
18 37 31.05	59 31 36.1	–	–	44.0	366 [b]	No ID [a]

[a] Outside EGRET 99% confidence error ellipse.

[b] WENSS catalogued flux corresponding to the sum of these two VLA sources.

Table 3. QSOs Selected by Ultraviolet Excess

Name	R.A. (h m s)	Decl. (° ′ ″)	B	z	Telescope
RX J1834.1+5913	18 34 08.24	59 13 51.0	19.3	0.973	Lick 3m
UVQ J1834.3+5926	18 34 20.65	59 26 50.7	20.5	2.21	Keck II
UVQ J1834.3+5918	18 34 21.07	59 18 45.8	20.2	0.504	MDM 2.4m
RX J1835.9+5923	18 35 53.71	59 23 29.6	19.6	1.87	MDM 2.4m
UVQ J1836.3+5929	18 36 16.21	59 29 06.4	20.0	1.33	MDM 2.4m
RX J1836.6+5920	18 36 36.90	59 20 41.9	21.3	1.36	HET
RX J1836.6+5925	18 36 38.62	59 25 25.5	19.8	1.75	MDM 2.4m
RX J1837.0+5934	18 37 00.48	59 34 16.3	18.5	1.278?[a]	MDM 1.3m

[a] An alternate identification of the single emission line in the spectrum of this object as Hγ would imply $z = 0.469$.

Fig. 1.— The combined GIS images (grey scale and contours) from the *ASCA* observation of 3EG J1835+5918. Positions of *ROSAT* HRI sources (from Table 1) are indicated by crosses.

Fig. 2.— Positions of quasars (asterisks) and radio sources (filled circles) in the field of 3EG J1835+5918. Radio sources have been drawn in proportion to their 1.4 GHz fluxes.

Fig. 3.— Finding charts for interesting objects selected from Tables 1–3. Each chart is $128''$ on a side. Circles indicate the statistical uncertainty in position for *ROSAT* and VLA sources. Arrows indicate high-confidence optical identifications based on the spectra displayed in Figures 4 and 5. UV excess QSOs have no error circles, since they were optically selected from the CCD images used to make these charts.

Fig. 4.— Continued from Figure 3.

Fig. 5.— Spectra of new quasars in the field of 3EG J1835+5918 obtained via UV excess, X-ray, and radio selection.

Fig. 6.— Continued from Figure 5. Spectra of new quasars in the field of 3EG J1835+5918. Also shown are the spectra of two radio galaxies, the brightest galaxy cluster member, and three X-ray emitting stars.

Fig. 7.— $BVRI$ images at the location of RX J1836.2+5925. Each chart is $64''$ on a side. The best X-ray position was derived by recalibrating the astrometry using the optical positions of well-identified sources as described in the text. Although an "error box" is drawn $8''$ on a side, we believe that the combined statistical and systematic error in position is no worse than $3''$ in radius. Detection limits are $U > 22.3, B > 23.4, V > 23.3$, and $R > 22.5$.

Fig. 8.— Asterisks are the collected radio, optical, X-ray, and γ-ray fluxes of EGRET blazars (Hartman *et al.* 1999; Mattox *et al.* 1997; Fossati *et al.* 1998). Shown for comparison are the EGRET spectral points from 3EG J1835+5918 (Reimer *et al.* 2000). In the absence of an

obvious identification from X-ray, optical, or radio data, we illustrate the properties of the brightest QSO within the error ellipse (RX J1834.1+5913, circles), and the brightest radio source within the error ellipse (VLA J1834.7+5918, triangles). The smooth curves fitted to these two candidates correspond to the sum of two empirical third-order polynomials.

Fig. 9.— The ratio of 4.85 GHz flux density from Mattox *et al.* (1997) to the peak γ-ray flux in the range $E > 100$ MeV for identified EGRET blazars is graphed as a function of γ-ray flux. The circle and triangle represent the same candidates as in Figure 8. We chose in this Figure to assume a flat radio spectrum for 3EG J1835+5918, although none of its faint candidates are actually detected at 4.85 GHz.

Fig. 10.— Comparison of (0.1-2.4 keV) X-ray flux (Becker & Trümper 1997) and average flux $E > 100$ MeV for EGRET pulsars (Fierro 1995; Kaspi *et al.* 2000; Ramanamurthy *et al.* 1995). The arrow corresponds to the X-ray upper limit from *ROSAT* observations of 3EG J1835+5918, assuming that the brightest unidentified *ROSAT* source in the error ellipse could be a pulsar.